HEATING AND DEFROSTING METHODS AND APPARATUS

TECHNICAL FIELD

The present invention in one embodiment relates to heat pump apparatus and to methods of operating a heat pump, and in particular, but not exclusively, to heat pumps which reduce or eliminate icing of the evaporator. It does, however, have application wherever fluid heating may be required.

BACKGROUND OF THE INVENTION

The term "heat pump" is used herein to define a system which absorbs heat (heat energy), at one or more temperatures and emits heat at a higher temperature, and which includes, in order, a compressor to pump refrigerant vapor around a closed circuit, a condenser to extract heat from the vapor, thereby condensing the refrigerant, an expansion valve to expand the refrigerant to a gaseous phase, thereby causing the temperature of the refrigerant to fall, and an evaporator to allow the cool refrigerant vapor to absorb heat.

The refrigerant then returns to the compressor and repeats the cycle. Elements such as accumulators and receivers may also be used to ensure that the fluid is in the correct phase before it proceeds around the cycle.

It is to be understood that the term heat pump may be applied equally to such systems when used to remove heat from a space or medium, such as for the purposes of air conditioning and refrigeration, or to systems used for heating a space or medium, such as water or space heating. Typically a four-way valve will be included in the heat pump system before the compressor to change-over the condenser to an evaporator and vice versa. The terms "evaporator" and "condenser" are therefore used interchangeably herein depending on whether the heat pump is being used in its heating or cooling mode. Other uses such as the heating of a gas or other fluids will also be included. Such uses could include the heating of a fluid such as in a hydraulic system or in an engine where lowering of the viscosity of the fluid could be of benefit. Further uses could include the heating of a gas, such as a compressed gas before its release when its cooling could create problems.

Heat pump technology is now very common and the savings gained through using this method for heating in addition to its more traditional role in air conditioning are now more widely appreciated. Many Governments and Authorities as well as Industry and Commerce are realizing the benefits. The need to save energy has become a priority around the world.

A disadvantage of using current heat pumps for heating is that ice may form on the evaporator when the ambient temperature around the evaporator drops below a minimum temperature, typically around +10°C. When this happens the efficiency of the heat pump reduces dramatically due to the low thermal conductivity of the ice reducing the rate at which heat can be absorbed by the evaporator.

One of the options currently used to combat icing of the evaporator is the provision of electric heating elements attached to the evaporator or embedded within it. In such systems the heat pump may be stopped and the refrigerant pumped down to the receiver before the evaporator is heated. Failure to stop the device may lead to liquid refrigerant entering the compressor, which may damage or even destroy it. Once the heat pump has been stopped the heating elements defrost the coil until the ice is melted and the unit can be run again. The heating element may cycle on and off many times until the ambient temperature increases.

A second method in use at present is a hot gas by-pass system. When the evaporator coil ices, a solenoid valve opens, and hot gas is directly injected into the evaporator just after the expansion device. This method of evaporator de-icing may affect the system's operation dramatically and performance may drop accordingly.

A further method currently in use is to reverse the heat pump so that the functions of the evaporator and condenser are reversed. A disadvantage of this method is that the heat transfer path is reversed, and the element which the heat pump is intended to heat is instead cooled for the duration of the de-icing cycle.

OBJECT OF THE INVENTION

It is an object of a preferred embodiment of the present invention to provide a heat pump apparatus and/or a method of operating a heat pump which will overcome or ameliorate problems with such apparatus or methods at present.

Other objects of the present invention may become apparent from the following description, which is given by way of example only.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a heat pump apparatus including an evaporator means, a control means in communication with at least one sensor means adapted to measure one or more variables representative of a temperature of an outer surface of said evaporator means, and a heat exchanger means operable to add heat from a working fluid from a high pressure side of said heat pump apparatus to said working fluid entering said evaporator, wherein said control means is operatively connected with said heat exchanger means to add said heat when said control means determines that said temperature of said outer surface of said evaporator means is below a pre-selected temperature, thereby reducing or substantially eliminating formation of ice on said outer surface of said evaporator.

Preferably, said heat exchanger means includes a helically corrugated tube positioned within an outer housing, said working fluid from said high pressure side being caused to flow through said tube to add heat to said working fluid caused to flow over said tube and between said tube and said outer housing.

Optionally, said at least one sensor means includes a temperature sensor adapted to measure the temperature of said outer surface of said evaporator.

Optionally, said at least one sensor means includes a temperature sensor adapted to measure the temperature of the working fluid exiting the evaporator.

Optionally, said at least one sensor means includes a temperature sensor adapted to measure the temperature of the environment surrounding the evaporator.

Optionally, said at least one sensor means includes a pressure sensor adapted to measure the pressure of the working fluid exiting the evaporator.

Optionally, said heat exchanger means includes an electric heating element.

Optionally, said heat exchanger means obtains heat from said working fluid between a compressor and a condenser of said heat pump apparatus to transfer said heat to said working fluid entering said evaporator means.

Optionally, said pre-selected temperature is between about 4°C and 0°C.

According to a second aspect of the present invention there is provided a heat pump apparatus including an evaporator means, a control means in communication with at least one sensor means adapted to measure one or more variables representative of a temperature of an outer surface of said evaporator means, and a heat exchanger means including a heating element positioned upstream of said evaporator means and downstream of an expansion means of said heat pump, the heat exchanger means operable to add heat to a working fluid entering said evaporator, wherein said control means is operatively connected with said heat exchanger means so that when said control means determines that said temperature of said outer surface of said evaporator means is below a pre-selected temperature the heat exchanger means adds heat to said working fluid thereby reducing or substantially eliminating formation of ice on said outer surface of said evaporator and wherein said heat exchanger means includes a helically corrugated tube positioned within an outer housing and said working fluid being heated is caused to flow over said tube and between said tube and said outer housing.

Optionally the helical tube includes said heating elements extending there through.

Optionally the helical tube forms part of the heating element.

Optionally, said at least one sensor means may include a temperature sensor adapted to measure the temperature of said outer surface of said evaporator.

Optionally, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the working fluid exiting the evaporator.

Optionally, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the environment surrounding the evaporator.

Optionally, said at least one sensor means may include a pressure sensor adapted to measure the pressure of the working fluid exiting the evaporator.

Optionally, said heat exchanger means may transfer heat from the working fluid on the high pressure side of said heat pump apparatus to the working fluid entering said evaporator.

Optionally, said heat exchanger means may transfer heat from the working fluid between said compressor and said condenser to the working fluid entering said evaporator.

Optionally, said working fluid may be returned to between said condenser and said expansion device after it has passed through said heat exchanger.

Optionally, said pre-selected temperature may be between 4°C and 0°C.

According to a third aspect of the present invention there is provided a method of operating a heat pump having an evaporator means downstream of an expansion means, the method including adding heat as required from a working fluid from a high pressure side of said heat pump to said working fluid, from a low pressure side of said heat pump, prior to said working fluid entering said evaporator means, to reduce or substantially prevent ice from forming on an outer surface of said evaporator means.

Optionally the method includes passing said working fluid through a heat exchanger and providing for the heat exchanger a helically corrugated tube over which the working fluid can flow as it is heated.

Optionally, the method includes measuring one or more variables representative of a temperature of an outer surface of said evaporator means and adding said heat to the working fluid entering said evaporator when said one or more variables indicate that said temperature has dropped below a pre-selected minimum.

Optionally, the method includes providing a controller to determine when icing of said evaporator means is imminent based on said measurements of said one or more variables.

Optionally, the method includes heating the working fluid entering said evaporator means with an electric heating element.

Optionally, the method includes heating the working fluid entering the evaporator means with heat from said working fluid between a compressor and a condenser of said heat pump.

Optionally, the method includes adding said heat to said working fluid while said heat pump is in operation.

According to a fourth aspect of the present invention, a heating apparatus for a fluid circuit includes a heat exchanger means operable to add heat to a fluid flowing in said circuit, at least one sensor means adapted to measure one or more variables representative of a temperature of said fluid, a control means in communication with said at least one sensor means and operatively connected with said heat exchanger means to add heat to said fluid when said control means determines that said temperature is below a pre-selected temperature.

According to a fifth aspect of the present invention, a heat pump and/or a method of operating a heat pump and/or a heating apparatus is substantially as herein described with reference to the accompanying drawings.

Further aspects of the present invention, which should be considered in all its novel aspects, will become apparent from the following description, given by way of example only and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1: Is a schematic diagram of a heat pump apparatus according to one possible embodiment of the present invention;

FIGURE 2A: Is a very diagrammatic cross-sectional view through a heat exchanger and heating element according to one possible embodiment of the present invention, with the spacing between the corrugated conduit and the outer layer of the heating element exaggerated for clarity;

FIGURE 2B: Is a very diagrammatic cross-sectional view through a heat exchanger and heating element according to another possible embodiment of the present invention;

FIGURE 3: Is a schematic diagram of a heat pump apparatus according to a further possible embodiment of the present invention, with two alternative flow paths for the refrigerant shown.;

FIGURE 4: Shows very diagrammatically, and in part a cross section, a heat exchanger for possible use with the present invention;

FIGURE 5: Shows very diagrammatically, and in part a cross section, an alternative embodiment of a heat exchanger for use in the present invention;

FIGURE 6: Shows very diagrammatically, and in part a cross section, a further possible embodiment of a heat exchanger for use in the present invention;

FIGURE 7A: Shows very diagrammatically, and in part cross section, a prior art heat exchanger for possible use with the present invention;

FIGURE 7B: Shows very diagrammatically a cross sectional view of the heat exchanger of Figure 7A.

BRIEF DESCRIPTION OF POSSIBLE EMBODIMENTS OF THE INVENTION

Referring first to Figure 1, a heat pump apparatus in accordance with one possible embodiment of the present invention is generally referenced 100. The heat pump 100 is illustrated with reference to its use as a heating circuit for heating water, but it is to be appreciated that the invention may also be used in applications where refrigeration or air conditioning are required.

The heat pump includes a compressor 1, condenser 2, an expansion means, for example an expansion valve 3, and an evaporator 4, in the same order and performing the same functions as those of the heat pumps of the prior art. A receiver and/or accumulator (not shown) may also be present as required. The condenser 2 provides heat to a suitable medium, for example a domestic hot water supply 5, the water flow being indicated by the upper arrows shown entering and leaving the condenser 2.

References herein to the "high pressure" side of the heat pump refer to that part of the circuit which the working fluid or "refrigerant" passes through between the compressor 1 and the expansion valve 3. References to the "low pressure" side of the heat pump refer to the remainder of the heat pump circuit.

According to one embodiment of the present invention the heat pump 100 further includes a heat exchanger 6 shown located immediately downstream of the expansion valve 3 and upstream of the evaporator 4.

A controller 8, for example a computer or microprocessor, but more preferably a Programmable Logic Controller (PLC), monitors one or more variables which allow it to predict that icing of the evaporator 4 is about to occur. Preferably, icing may be predicted by determining that the temperature of an exterior surface of the evaporator 4 is below a predetermined temperature, for example between 4°C and 0°C.

The temperature of the exterior surface of the evaporator 4 may be determined by direct measurement or may be calculated through measurements of other variables, for example through use of a lookup table.

The variables measured may include one or more of the temperature of the ambient air around the evaporator 4, the temperature of the refrigerant leaving the evaporator 4, the surface temperature of the evaporator 4 or the pressure of the refrigerant leaving the evaporator 4, this pressure known as the "suction pressure" being well known as having a direct relationship to the icing of the evaporator of a heat pump. Other variables may also be monitored as will be apparent to those skilled in the art. Figure 1 shows a sensor 10 monitoring the temperature of the refrigerant leaving the evaporator 4 and communicating information related to the temperature to the controller 8.

When the variable(s) sensed by the controller 8 is/are indicative of a state in which ice may form on the evaporator 4, that is, on an exterior surface of the evaporator coils (not shown), the controller 8 may activate the electric heating element 7, thereby heating the refrigerant entering the evaporator 4. This may be continued until the variables sensed by the controller 8 reach a threshold at which ice formation is no longer likely. At this point the controller 8 may switch the heating element 7 off. The controller 8 may continue to monitor the variables and may continue to switch the heating element 7 on and off as required.

Heating the refrigerant in this way may avoid icing of the evaporator 4 without the need stop the heat pump 100. Those skilled in the art will appreciate that at least a portion of the energy added to the system by the heating element 7 may be recovered as heat from the condenser 2.

Referring next to Figure 2, as will be known to those skilled in the art, a typical electric element 7 includes a resistive element 12, a heat conducting but electrically resistive material 13 surrounding the resistive element 12, and an outer layer 14. In the heat exchanger 6 of the present invention a helically corrugated tube or conduit 15 may be provided over the outer layer 14 in sufficiently close contact to allow conduction of heat from the outer layer 14 to the conduit 15. The helically corrugated tube or conduit 15 may preferably be formed using the method described in the Applicant's PCT specification WO 94/07071, in order to improve the exchange of heat between the element 7 and the refrigerant 16.

In an alternative embodiment of the present invention, as illustrated in Figure 2B, a helically corrugated layer 15 may replace the outer layer 14.

Referring next to Figure 3, a second possible embodiment of the heat pump is shown generally referenced by arrow 200, with similar reference numerals used for similar features.

The heat pump 200 also includes a heat exchanger 6a and a controller 8. The controller 8 may sense the "suction pressure" in the compressor suction line 9 with a pressure sensor 11, although other variables may additionally or alternatively be sensed as described above.

When the pressure in the suction line 9 falls below a pre-selected minimum, the controller 8 may allow hot refrigerant from the high pressure side of the heat pump to flow through an intake pipe 17 to the heat exchanger 6a, thereby heating the refrigerant immediately upstream of the evaporator 4 and preventing ice from forming on the evaporator 4.

The hot refrigerant may be taken from anywhere on the high pressure side of the cycle, but preferably from between the compressor 1 and condenser 2, where the refrigerant is at its highest temperature. The hot fluid is preferably returned via an outlet pipe 18 to the downstream side of the condenser 2 after passing through the heat exchanger 6a, although in some embodiments the fluid may be returned to substantially the same point in the cycle after passing through the heat exchanger 6a, as illustrated in outline by outlet pipe 18a.

When the controller 8 determines that icing is no longer imminent the flow of hot refrigerant to the heat exchanger 6a may be ceased to allow the apparatus 200 to perform at maximum efficiency. In a preferred embodiment the controller 8 may be a simple mechanical valve which is activated by changes in the pressure of the compressor suction line 9.

Referring now to Figure 4 of the accompanying drawings, this shows very diagrammatically a heat exchanger for suitable use in the present invention and with corresponding reference numerals as those used in the previous drawings being also used. The heat exchanger 6 is shown having an outer housing or sleeve 20 provided with an inlet 21 and an outlet 22 for the flow in a direction indicated by arrows X of the refrigerant to be heated. Within the outer housing or sleeve 20 is shown a helically corrugated tube or conduit 15 defining a refrigerant flow passage 16 between the tube 15 and the outer housing or sleeve 6. An electric element 12 is shown extending through the helical tube 15 with electrical connections 17 and 18. Typically, surrounding the electric element 12 will be a core of magnesium oxide or the like. The helical tube 15 of Figure 4 and the subsequent Figures 5 and 6 may suitably be manufactured in accordance with the applicant's PCT specification WO 94/07071.

Turning then to Figure 5, in an alternative embodiment of heat exchanger 6, a helically corrugated tube or conduit 15 is again provided within an outer housing or sleeve 20 to provide the helical flow path 16 for the refrigerant flowing in the direction of arrows

X. However, the helical tube 15 may, in this embodiment, form part of the electrical heating element and be part of the electrical circuit between terminals 18 and 17, so as to provide a direct heating of the refrigerant flowing over the helical corrugated surface.

Referring then to Figure 6, in a further embodiment a working fluid will be caused to flow in a direction indicated by arrows B through the helical tube 15, the fluid being at an elevated temperature so as to provide a heat energy transfer through the helically corrugated tube 15 to the refrigerant flowing in the direction of arrows X-X.

This embodiment of heat exchanger 6 will be of particular use in the embodiment of Figure 3.

Referring then to an alternative form of heat exchanger as shown in Figure 7, this type of heat exchanger is disclosed in WO 98/27395 and is again shown with an outer housing or sleeve 20 providing an inlet 21 and an outlet 22 for refrigerant flow in a direction of arrows X. Within the outer sleeve 20 is shown a tube or conduit 23 with corrugations 24 which in this example are indicated as extending longitudinally along the axis of the heat exchanger 6. An electric heating element 12 is shown extending through the tube or conduit 23 as shown in Figure 7B. A barrier 25 extends the length of the heat exchanger 6 so that the refrigerant must traverse both circumferentially and longitudinally about the tube or conduit 23 between the inlet and outlet 21 and 22 to maximize heat transfer.

Those skilled in the art will appreciate that the embodiments shown in Figures 1 and 3 may be combined as necessary, and the controller 8 may determine whether to use either heating method alone or both in combination.

Those skilled in the art will also appreciate that by preventing ice from forming on the evaporator 4 without stopping the refrigerant flow, the present invention may be more efficient than the heat pumps of the prior art when used in environments where icing of the evaporator may occur, for example those in which the ambient temperature drops below around 10°C.

Also it will be appreciated that the present invention could be used in numerous other situations for the heating of a fluid. It is envisaged, for example, that liquid petroleum gas (LPG) being removed from an LPG cylinder could be heated using a heat

exchanger, such as shown in Figures 4, 5 or 6 for example. In this way the LPG can be converted to a gas external of the LPG cylinder which could otherwise be in danger of freezing if LPG is drawn off at too fast a rate. Alternatively, a compressed gas could be heated before it is released so as to avoid the unwanted cooling of the gas at its lowering of pressure. Further, a fluid in a hydraulic circuit or engine could be heated when required to thin it and lower its viscosity which can be of benefit such as in the starting of diesel engines for example. Also, the present invention could be used in refrigeration circuits such as of a domestic or commercial refrigerator.

Where in the foregoing description, reference has been made to specific components or integers of the invention having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made thereto without departing from the scope of the invention as defined in the appended claims.